Mathematical Modeling of SCOLE Configuration with Line-of-Sight Error as the Output

by

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Mathematical Modeling of the SCOLE Configuration with Line-of Sight Error as the output

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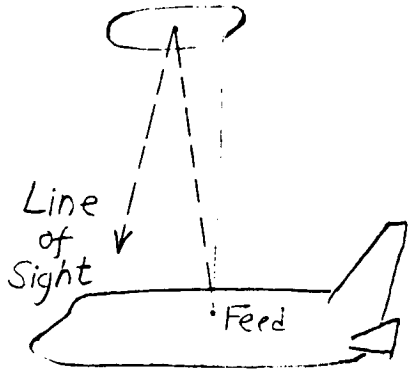


I-SCOLE Linear Model

3 - Rigid-body modes + 10 Flex. modes
(order = 26)

5 inputs $[M_x, M_y, M_z, F_x, F_y]$

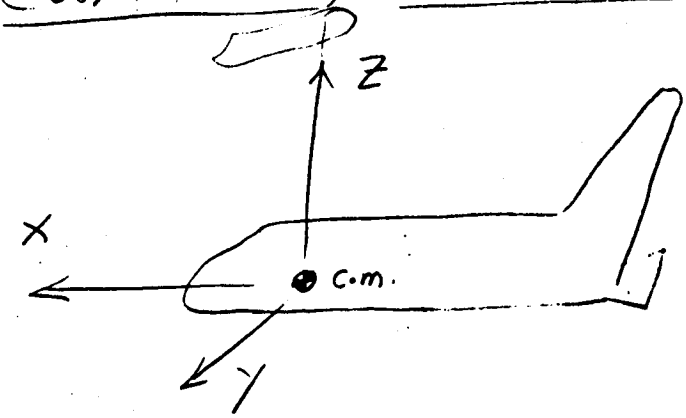
M_x, M_y, M_z: Moments applied at shuttle

F_x, F_y: Forces Applied at reflector ctr.

3 outputs $y = \Delta L.O.S.$

(3-dim. error in Line-of-sight vector)

Coordinate System: D. Roberts



Units : FPS System

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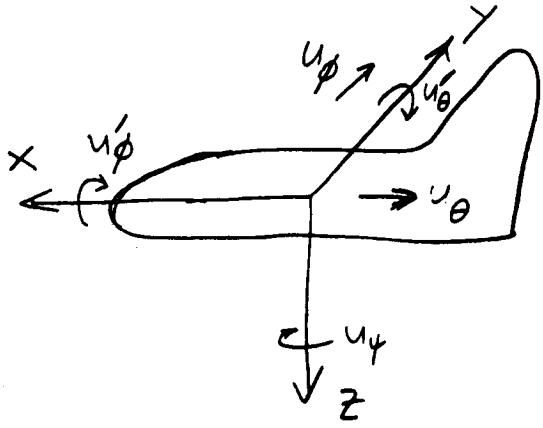
Expression for linearized LOS error

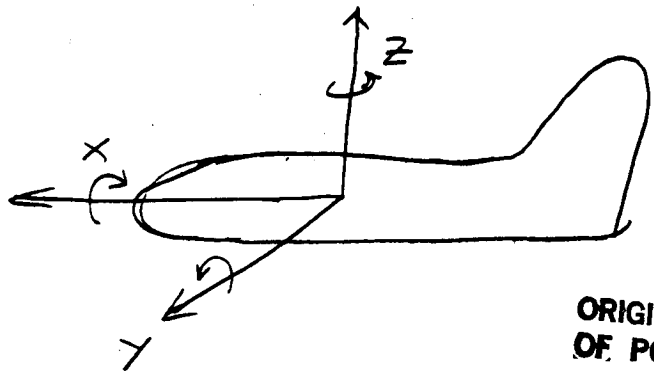
If everything is in Robertson's coordinate system the linearized LOS error is:

$$\Delta_{LOS} \equiv \begin{vmatrix} -L\theta_s + r_y\psi_s + u_\theta(L) - u_\theta(0) + r_y u_\psi(L) - 2L u_\theta'(L) \\ L\phi_s + r_x\psi_s + u_\phi(L) - u_\phi(0) + r_x u_\psi(L) - 2L u_\phi'(L) \\ -r_x\theta_s - r_y\phi_s - r_x u_\theta'(L) + r_y u_\phi'(L) \end{vmatrix}$$

(Where ϕ_s, θ_s, ψ_s are the rigid-body angles about x, y, z axes.)

u_θ, u_ϕ are elastic deflections; $u_\phi', u_\theta', u_\psi$ are elastic angular deflections





Taylor's coordinate system

X-defl.	$-u_\theta$
Y-defl.	u_ϕ
Angular defl. (about X)	u_ϕ'
Angular defl. (about Y)	u_θ'
Angular defl. (about Z)	u_ψ

nominal
Coordinates of refl. c.m. rel. to shuttle

$(r_x, r_y, -L)$ $r_x = 18.75$, $r_y = -32.5$, $L = 130.$

Robertson's system

X-defl.	u_θ
Y-defl.	u_ϕ
Angular defl. (about x-axis)	$-u_\phi'$
Angular defl. (about y-axis)	u_θ'
Angular defl. (about z-axis)	u_ψ

$(r_x, -r_y, L)$

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LOAD MAP - CONTROL

CYBER LOADER 1.5-552 86/11/04. 16.00.26. PAGE 81

1.411 CP SECONDS 523008 CM STORAGE USED 89 TABLE MOVES

A (26×26)

$x =$ ϕ_1, θ_1, ψ_1 (rigid-body attitude); $\dot{\phi}_1$, $\dot{\theta}_1$, $\dot{\psi}_1$ (rigid-body rates); q_1, $\dot{q}_1$ (Flex. Mode 1); q_2, $\dot{q}_2$; ... q_{10}, $\dot{q}_{10}$ (Flex. Mode 10) — 26×1

1st row
2nd row
3rd row

.10000E+01
.16000E+01
.10000E+01
.10000E+01
-.30520E+01 -.10482E-01
.10000E+01
.10000E+01
-.38819E+01 -.11821E-01
.10000E+01
-.26094E+02 -.30650E-01
.10000E+01
-.55494E+02 -.44697E-01
.10000E+01

Row 15

Cont.

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$A_{26\times26}$ (contd. from previous page)

Row 16	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	-.16650E+03	-.77420E-01	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.				
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	.10000E+01	0.	0.
	0.	0.	0.	0.	0.	0.				
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	-.89557E+03	-.17956E+00	0.	0.
	0.	0.	0.	0.	0.	0.				
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	.10000E+01
	0.	0.	0.	0.	0.	0.				
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	-.12011E+04	-.20794E+00
	0.	0.	0.	0.	0.	0.				
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	.10000E+01	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.				
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	-.59545E+04	-.46299E+00	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.				
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	.10000E+01	0.	0.				
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	-.65599E+04	-.48596E+00	0.	0.				
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	.10000E+01				
26th Row	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	-.22136E+05	-.89270E+00				

B (26×5)

0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
.88486E-06	-.10610E-08	.14337E-07	-.59958E-06	-.11476E-03
-.10610E-08	.14272E-06	-.10662E-08	.18588E-04	.11794E-06
.14337E-07	-.10662E-08	.14081E-06	-.46726E-05	.77638E-06
0.	0.	0.	0.	0.
-.14847E-03	-.67762E-03	.48084E-04	.19876E+01	-.62670E-01
0.	0.	0.	0.	0.
.51993E-02	-.45857E-04	-.26141E-04	.14599E+00	.26186E+01
0.	0.	0.	0.	0.
-.32276E-03	-.73050E-04	-.30638E-04	.10032E+01	-.56127E+00
0.	0.	0.	0.	0.
.71189E-03	-.54339E-04	.35905E-07	.27669E+00	.48924E+00
0.	0.	0.	0.	0.
-.18890E-03	-.43101E-04	.21200E-06	-.91695E-01	.51606E-01
0.	0.	0.	0.	0.
.12068E-03	-.93335E-05	.24659E-09	-.15570E+00	-.26696E+00
0.	0.	0.	0.	0.
-.62175E-04	-.14263E-04	.14394E-06	-.37195E+00	.21550E+00
0.	0.	0.	0.	0.
.45351E-04	-.35004E-05	-.33958E-10	.10385E+00	.17885E+00
0.	0.	0.	0.	0.
-.25440E-04	-.58583E-05	-.19414E-07	.31226E+00	-.18050E+00
0.	0.	0.	0.	0.
.23310E-04	-.17963E-05	.56658E-11	-.76610E-01	-.13216E+00

$$u = \begin{bmatrix} M_x \\ M_y \\ M_z \\ \cdots \\ F_x \\ F_y \end{bmatrix}_{5\times 1}$$

M_x, M_y, M_z: Applied moments at shuttle.

F_x, F_y: Appld. forces at reflector.

C (3×26)

$$y = [\Delta L.O.S.]_{3\times 1}$$

Row 1	0.	-.13000E+03	-.32200E+02	0.	0.	0.	-.34352E+00	0.	-.81771E-01	0.		
	-.40647E+00	0.	.57773E+00	0.	.13541E+01	0.	-.88903E-01	0.	-.55986E+00	0.		
	.36432E-01	0.	.21907E+00	0.	-.20755E-01	0.						
Row 2	.13000E+03	0.	.18750E+02	0.	0.	0.	-.93853E-02	0.	.86560E+00	0.		
	-.25707E+00	0.	-.88594E+00	0.	.79047E+00	0.	.10136E+00	0.	-.30605E+00	0.		
	-.28930E-01	0.	.11102E+00	0.	.11240E-01	0.						
Row 3	.32200E+02	-.18750E+02	0.	0.	0.	0.	-.38918E-01	0.	.76339E-01	0.		
	-.65548E-01	0.	-.75790E-01	0.	.19557E+00	0.	.10363E-01	0.	-.78259E-01	0.		
	-.37941E-02	0.	.29526E-01	0.	.19829E-02	0.						

II- SCOLE - Flexible linear model

(10 Flex. modes only)

8 inputs
14 outputs
} as described

Coordinate System: D. Robertson's

FPS Units

Note: For control of LOS using ΔLOS measurements, the previous model which includes rigid + 10 flex. modes should be adequate. The following model is provided for those wishing to use additional inputs or outputs. This can be accomplished by selecting appropriate elements of "B" and "C" matrices. Note that the following model contains only flex. modes since its purpose is to supplement the previous (rigid + elastic) model.

SCOLE - Flexible model (10 modes)

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5/22/85

(The state, input, output variables are defined in the SCOLE w/s presentation (Dec '84)

NO. OF MODES= ION= 20 M= 8 L= 14
A MATRIX (20x20)

$$X = \begin{bmatrix} q_1 \\ \dot{q}_1 \\ q_2 \\ \dot{q}_2 \\ \vdots \\ q_{10} \\ \dot{q}_{10} \end{bmatrix}_{20\times 1}$$

0.	.10000E+01	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
-.30520E+01	-.10482E-01	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	.10000E+01	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	-.38819E+01	-.11821E-01	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	.10000E+01	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	-.26094E+02	-.30650E-01	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	.10000E+01	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	-.55494E+02	-.44697E-01	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	.10000E+01
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	-.16650E+03	-.77420E-01

0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	.10000E+01	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
-.89557E+03	-.17956E+00	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	.10000E+01	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	-.12011E+04	-.20794E+00	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	.10000E+01	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	-.59545E+04	-.46299E+00	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	.10000E+01	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	-.65599E+04	-.48596E+00	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	.10000E+01
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	-.22136E+05	-.89270E+00

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$u = [M_x, M_y, M_z, F_x, F_y, M_{rx}, M_{ry}, M_{rz}]^T$ (8×1)

M_x, M_y, M_z: Moments appld. at shuttle

M_{rx}, M_{ry}, M_{rz}: Moments appld. at reflector

F_x, F_y: Forces applied at reflector c.m.

B MATRIX (20 × 8)

0.	0.	0.	0.	0.	0.	0.	0.
-.14847E-03	-.67762E-03	.48084E-04	.19876E+01	-.62670E-01	-.35536E-03	.22331E-01	-.33316E-02
0.	0.	0.	0.	0.	0.	0.	0.
.51993E-02	-.45857E-04	-.26141E-04	.14599E+00	.20186E+01	-.26714E-01	.32714E-02	.23108E-02
0.	0.	0.	0.	0.	0.	0.	0.
-.32276E-03	-.73050E-04	-.30038E-04	.10032E+01	-.58127E+00	.10762E-01	.18102E-01	.18013E-01
0.	0.	0.	0.	0.	0.	0.	0.
.71189E-03	-.54339E-04	.35905E-07	.27669E+00	.40924E+00	.37542E-01	-.22172E-01	-.45803E-04
0.	0.	0.	0.	0.	0.	0.	0.
-.18890E-03	-.43101E-04	.21280E-06	-.91695E-01	.51600E-01	-.31739E-01	-.54643E-01	-.81304E-03
0.	0.	0.	0.	0.	0.	0.	0.
.12068E-03	-.93335E-05	.51659E-09	-.15570E+00	-.26696E+00	-.51053E-02	.29835E-02	-.10460E-04
0.	0.	0.	0.	0.	0.	0.	0.
-.62175E-04	-.14263E-04	.11394E-06	-.37195E+00	.21550E+00	.12693E-01	.21880E-01	-.30748E-02
0.	0.	0.	0.	0.	0.	0.	0.
.45351E-04	-.35004E-05	-.33958E-10	.10365E+00	.17885E+00	.18544E-02	-.10671E-02	.41097E-05
0.	0.	0.	0.	0.	0.	0.	0.
-.25440E-04	-.58583E-05	-.19414E-07	.31226E+00	-.18050E+00	-.47872E-02	-.82578E-02	.25549E-02
0.	0.	0.	0.	0.	0.	0.	0.
.23310E-04	-.17963E-05	.56858E-11	-.76610E-01	-.13216E+00	-.95988E-03	.54178E-03	-.17527E-05

(Flexible part only) → $y = [\phi_0, \theta_0, \psi_0, \dot{\phi}_0, \dot{\psi}_0, \dot{\theta}_0, \xi_x, \xi_y, \phi_R, \theta_R, \psi_R, \dot{\phi}_R, \dot{\theta}_R, \dot{\psi}_R]^T$ (20×1)

ϕ_0, θ_0, ψ_0: Attd. at shuttle

ξ_x, ξ_y: Deflection at beam tip rel. to base

ϕ_R, θ_R, ψ_R: Attitude at reflector

C Matrix (14×20)

1	-.14186E-04	0.	.49685E-03	0.	-.30843E-04	0.	.68028E-04	0.	-.18051E-04	0.									
	.11532E-04	0.	-.59415E-05	0.	.43338E-05	0.	-.24310E-05	0.	.22275E-05	0.									
2	-.64753E-04	0.	-.43821E-05	0.	-.69806E-03	0.	-.51927E-05	0.	-.41188E-05	0.									
	-.89191E-06	0.	-.13630E-05	0.	-.33450E-06	0.	-.55982E-06	0.	-.17165E-06	0.									
3	.13978E-04	0.	-.75992E-05	0.	-.87321E-05	0.	.10438E-07	0.	.61862E-07	0.									
	.15017E-09	0.	.33122E-07	0.	-.98715E-11	0.	-.56438E-08	0.	.16528E-11	0.									
4	0.	-.14186E-04	0.	.49685E-03	0.	-.30843E-04	0.	.68028E-04	0.	-.18051E-04									
	0.	.11532E-04	0.	-.59415E-05	0.	.43338E-05	0.	-.24310E-05	0.	.22275E-05									
5	0.	-.64753E-04	0.	-.43821E-05	0.	-.69806E-05	0.	-.51927E-05	0.	-.41188E-05									
	0.	-.89191E-06	0.	-.13630E-05	0.	-.33450E-06	0.	-.55982E-06	0.	-.17165E-06									
6	0.	.13978E-04	0.	-.75992E-05	0.	-.87321E-05	0.	.10438E-07	0.	.61862E-07									
	0.	.15017E-09	0.	.33122E-07	0.	-.98715E-11	0.	-.56438E-08	0.	.16528E-11									
7	-.18013E+00	0.	.21140E-01	0.	.15169E+00	0.	.26425E-01	0.	-.11169E-01	0.									
	-.14875E-01	0.	-.45033E-01	0.	.99586E-02	0.	.37812E-01	0.	-.73107E-02	0.									
8	-.55188E-04	0.	.18927E+00	0.	-.87665E-01	0.	.47052E-01	0.	.63186E-02	0.									
	-.25430E-01	0.	.26068E-01	0.	.17121E-01	0.	-.21848E-01	0.	-.12599E-01	0.									
9	-.33959E-04	0.	-.25528E-02	0.	.10284E-02	0.	.35875E-02	0.	-.30330E-02	0.									
	-.48786E-03	0.	.12129E-02	0.	.17720E-03	0.	-.45746E-03	0.	-.91726E-04	0.									
10	.21340E-02	0.	.31262E-03	0.	.17298E-02	0.	-.21168E-02	0.	-.52217E-02	0.									
	.28510E-03	0.	.20908E-02	0.	-.10197E-03	0.	-.78912E-03	0.	.51772E-04	0.									
11	-.96830E-03	0.	.67175E-03	0.	.52363E-02	0.	-.13319E-04	0.	-.23635E-03	0.									
	-.30409E-05	0.	-.89385E-03	0.	.11947E-05	0.	.74270E-03	0.	-.56930E-06	0.									
12	0.	-.33959E-04	0.	-.25528E-02	0.	.10284E-02	0.	.35875E-02	0.	-.30330E-02									
	0.	-.48786E-03	0.	.12129E-02	0.	.17720E-03	0.	-.45746E-03	0.	-.91726E-04									
13	0.	.21340E-02	0.	.31262E-03	0.	.17298E-02	0.	-.21168E-02	0.	-.52217E-02									
	0.	.28510E-03	0.	.20908E-02	0.	-.10197E-03	0.	-.78912E-03	0.	.51772E-04									
14	0.	-.96830E-03	0.	.67175E-03	0.	.52363E-02	0.	-.13319E-04	0.	-.23635E-03									
	0.	-.30409E-05	0.	-.89385E-03	0.	.11947E-05	0.	.74270E-03	0.	-.56930E-06									

Note: y contains flexible part only. Rigid-body components may be added to get the complete output.

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